Validation of recent versions for the GOSAT and GOSAT-2 FTS SWIR L2 products

NIES JAPAN TO CON total carbon column observing

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Used data

1. GOSAT SWIR L2 data: V02.90/02.91

• The validation was made using the data V02.90 during April 2009 ~ May 2020 and the data V02.91 during June 2020 ~ March 2021.

2. GOSAT-2 SWIR L2 Full Physics data:

- The validation was made using the V01.04 data during March 1, 2019~ May 18, 2020
- Area type: Land and Ocean (Land: >= Land Fraction 10%, Ocean: < Land Fraction 10%)

3. GOSAT-2 SWIR L2 PROXY data:

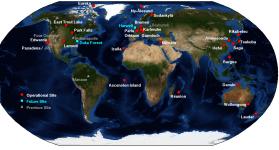
- The validation was made using the V.01.03 data during March 1, 2019 ~ February 29, 2020.
- Area type: Land and Ocean (Land: >= Land Fraction 10%, Ocean: < Land Fraction 10%)

4. TCCON data: GGG2014

- obtained from the TCCON data archive (<u>https://tccondata.org</u>)
- GOSAT and GOSAT FP: without consideration of column averaging kernels and a priori profiles for the quick validation analysis
- data whose measurement altitude difference between GOSAT and TCCON are larger than 500 m are not used.

Coincidence criteria for comparisons

- 1. GOSAT SWIR L2 data:
- obtained by ±2^o coincidence criteria (±2^o box area centered at the TCCON site)
- 2. TCCON data :
 - averaged over within ± 30 min of GOSAT overpass time



The TCCON Data Archive https://tccondata.org/

Summary of validation GOSAT (V02.90/20.91)

Area	Gain	XCO ₂			XCH4			XH ₂ O		
		Ν	Bias	S.D.	Ν	Bias	S.D.	Ν	Bias	S.D.
Land	н	8727	-0.41 ppm (-0.10%)	2.12 ppm (0.53%)	8746	-2.22 ppb (-0.12%)	12.20 ppb (0.67%)	8746	-59.75 ppm (-1.13%)	376.28 ppm (18.98%)
Land	м	1591	0.65 ppm (0.16%)	2.03 ppm (0.50%)	1591	10.71 ppb (0.58%)	19.77 ppb (1.07%)	1591	161.57 ppm (14.24%)	580.51 ppm (35.48%)
Ocean	н	139	-1.34 ppm (-0.33%)	2.18 ppm (0.54%)	139	0.24 ppb (0.01%)	13.50 ppb (0.74%)	139	-110.58 ppm (-2.12%)	622.99 ppm (12.18%)

GOSAT-2

	Area		XCO ₂		XCH4			
	Alea	Ν	Bias	S.D.	N	Bias	S.D.	
Full Physics (V01.04)	Land	2640	2.34 ppm (0.57%)	4.04 ppm (0.98%)	2654	-0.03 ppb (-0.00%)	19.33 ppb (1.04%)	
	Ocean	92	-0.14 ppm (-0.03%)	5.79 ppm (1.41%)	102	-11.7 ppb (-0.63%)	22.97 ppb (1.25%)	
			XH ₂ O		хсо			
		Ν	Bias	S.D.	Ν	Bias	S.D.	
	Land	2654	51.84 ppm (3.86%)	413.86 ppm (21.28%)	2650	21.16 ppb (25.05%)	8.45 ppb (10.27%)	
	Ocean	104	-43.76 ppm (1.4%)	567.88 ppm (16.25%)	101	18.66 ppb (22.92%)	7.64 ppb (8.91%)	
	Area		XCH4		хсо			
	Alea	N	Bias	S.D.	N	Bias	S.D.	
PROXY	Land	4340	-5.93 ppb (-0.32%)	13.57 ppb (0.73%)	2474	10.63 ppb (12.55%)	8.28 ppb (9.50%)	
(V01.03)	Ocean	226	-13.00 ppb (-0.71%)	15.94 ppb (0.86%)	96	7.79 ppb (9.55%)	11.37 ppb (13.50%)	

Scatter diagrams of GOSAT FTS SWIR L2 (V02.90/02.91) and TCCON at all TCCON sites and differences

N: total number of matched data

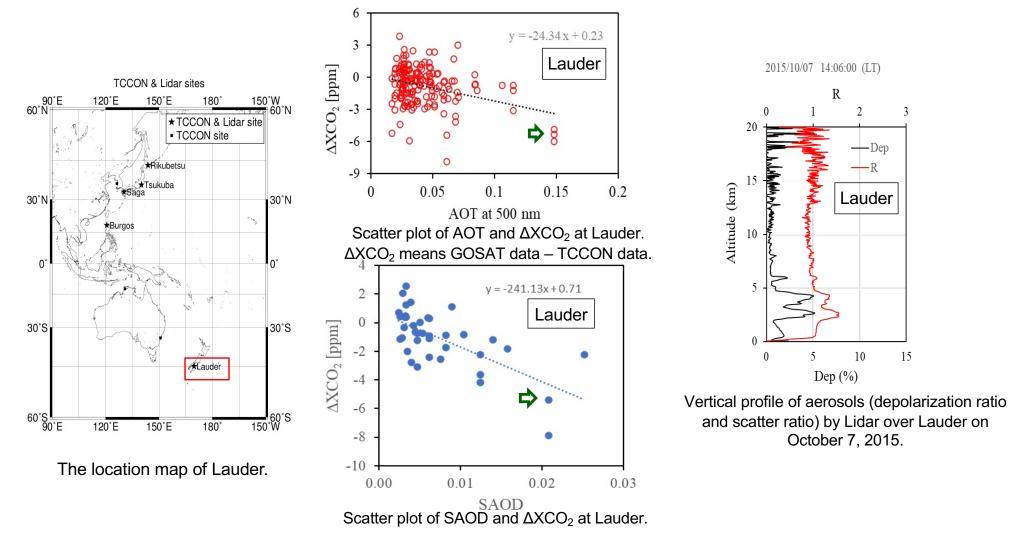
between them with 1 standard deviation (± 2 degree)

xco₂

AT

XCO₂ y=x+b ±2deg YRall Site:all XCH₄ y=x+b ±2deg YRall Site:all XH₂O y=x+b ±2deg YRall Site:all GO:V02.9x 20090423-20210331/TC:202103 GO:V02.9x 20090423-20210331/TC:202103 GO:V02.9x 20090423-20210331/TC:202103 425 1960 10000 Land Gain-H (n=8727) Land Gain-H (n=8746) Land Gain-H (n=8746) 420 9000 Land Gain-M (n=1591) Land Gain-M (n=1591) Land Gain-M (n=1591) 1920 Ocean Gain-H (n=139) Ocean Gain-H (n=139) Ocean Gain-H (n=139) 415 8000 1880 [mdd] F 410 7000 d 1840 Id 405 6000 XH₂O b 1800 400 5000 LYSO 1760 GOSAT 395 4000 0 0 390 3000 1720 385 2000 1680 380 1000 1640 375 380 385 390 395 400 405 410 415 420 425 1640 1680 1720 1760 1800 1840 1880 1920 1960 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 375 0 TCCON XCO₂ [ppm] TCCON XCH₄ [ppb] TCCON XH₂O [ppm] Land Gain H N= 8727 -0.41 \pm 2.12 ppm (-0.10 \pm 0.53%) Land Gain H N= 8746 Land Gain H N= 8746 $-2.22 \pm 12.20 \text{ ppb} (-0.12 \pm 0.67\%)$ $-59.75 \pm 376.28 \text{ ppm}(-1.13 \pm 18.98\%)$ Land Gain M N= 1591 $0.65 \pm 2.03 \text{ ppm} (0.16 \pm 0.50\%)$ Land Gain M N= 1591 $10.71 \pm 19.77 \text{ ppb} (0.58 \pm 1.07\%)$ $161.57 \pm 580.51 \text{ ppm} (14.24 \pm 35.48\%)$ Land Gain M N= 1591 Ocean Gain H N= $139 -1.34 \pm 2.18$ ppm (-0.33 $\pm 0.54\%$) Ocean Gain H N= 139 $0.24 \pm 13.50 \text{ ppb} (0.01 \pm 0.74\%)$ Ocean Gain H N= 139 $-110.58 \pm 622.99 \text{ ppm}(-2.12 \pm 12.18\%)$ XCO_2 XCH₄ XH₂O XCO₂ Bias (GOSAT - TCCON) +2deg YBal XCH, Bias (GOSAT - TCCON) + 2deg YBal GO:V02.9x 20090423-20210331/TC:202103 GO:V02.9x 20090423-20210331/TC:202103 XH₂O Bias (GOSAT - TCCON) ±2deg YR:all GO:V02.9x 20090423-20210331/TC:202103 Eureka (80.05 , 610) Eureka (80.05 , 610) Land Gain-H Eureka (80.05 , 610) Nv-Alesund (78.92, 20) Nv-Alesund (78.92, 20) Land Gain-H Land Gain-M Ny-Alesund (78.92, 20) Land_Gain-M Ocean Gain-H Sodankyla (67.37 , 118) Sodankyla (67.37 , 118) Ocean Gain-H Sodankyla (67.37 , 118) East_Trout_Lake (54.35 , 502) East_Trout_Lake (54.35 , 502) East Trout Lake (54.35 . 502) Bialystok (53.23 . 180) Bialystok (53.23 . 180) Bialystok (53.23 , 180) Bremen (53.10 , 27) Bremen (53.10 , 27) Bremen (53.10 . 27) Karlsruhe (49.10 , 116) Karlsruhe (49.10 , 116) Karlsruhe (49.10 . 116) Paris (48.85 . 60) Paris (48.85 . 60) Paris (48.85 60) Orleans (47.97 , 130) Orleans (47.97 , 130) Orleans (47.97 . 130) Garmisch (47.48 , 740) Garmisch (47.48 , 740) Garmisch (47.48 740) Zugspitze (47.42 , 2,960) Zugspitze (47.42 , 2,960) Zugspitze (47.42 , 2,960) Parkfalls (45.95 , 440) Parkfalls (45.95 , 440) Parkfalls (45.95 . 440) Rikubetsu (43.46 , 380) Rikubetsu (43.46 , 380) Rikubetsu (43.46 , 380) Indianapolis (39.86 270) Indianapolis (39.86 , 270) Indianapolis (39.86 , 270) Fourcorners (36.80 , 1,643) Fourcorners (36.80 , 1,643) Eourcorners (36.80 1.643) Lamont (36.60 , 320) Lamont (36.60 , 320) Lamont (36.60 . 320) Anmeyondo (36.54 , 30) Anmevondo (36.54 , 30) Land Gain-H Tsukuba (36.05 , 30) Tsukuba (36.05 , 30) - Land_Gain-M Tsukuba (36.05 . 30) Ocean Gain-Nicosia (35.14 , 185) Nicosia (35.14 , 185) Nicosia (35.14 , 185) Edwards (34.96 . 700) Edwards (34.96 . 700) Edwards (34.96 , 700) [pl02 (34.20 , 390) lpl02 (34.20 , 390) JpI02 (34.20 , 390) NO: Pasadena (34.14 , 230) Pasadena (34.14 , 230) Pasadena (34.14 230) Saga (33.24 , 7) Saga (33.24 . 7) Saga (33.24, Hefei (31.91 , 29) Hefei (31.91 , 29) Hefei (31.91 , 29) Izana (28.30 , 2,370) Izana (28.30 , 2,370) Izana (28.30, 2.370) Burgos (18.53 , 35) Burgos (18.53 , 35) Burgos (18.53 , 35) Manaus (-3.21 , 50) Manaus (-3.21 , 50) Manaus (-3.21 , 50) Ascension (-7.93 , 10) Ascension (-7.93 , 10) Ascension (-7.93 . 10) Darwin (-12.42, 37) Darwin (-12.42, 37) Darwin (-12.42, 37) Reunion (-20.90 , 87) Reunion (-20.90, 87) Reunion (-20.90, 87) Wollongong (-34.41 . 30) Wollongong (-34.41, 30) Wollongong (-34.41, 30) Lauder03 (-45.04 , 370) Lauder03 (-45.04 370) Lauder03 (-45.04, 370) Lauder02 (-45.04 . 370) Lauder02 (-45.04, 370) Lauder02 (-45.04, 370) Lauder01 (-45.04, 370) Lauder01 (-45.04 , 370 Lauder01 (-45.04, 370) ALL ALL -300 -240 -180 -120 -60 60 120 180 240 300 -15 -10 -5 0 10 15 -25 -20 5 20 -120 80 25 -80-400 120 GOSAT XH2O - TCCON XH2O [%] GOSAT XCO2 - TCCON XCO2 [ppm] GOSAT XCH4 - TCCON XCH4 [ppb] Data Max/Min red dott:Mei box:25/75% Black line: box:25/75% Black line:Median whisker:Data Max/Min red dott:Mean Max/Min_red_dott-Mean box:25/75% Black line:Median whisker:Da

GOSAT FTS SWIR XCO₂ biases by stratospheric aerosols at Lauder

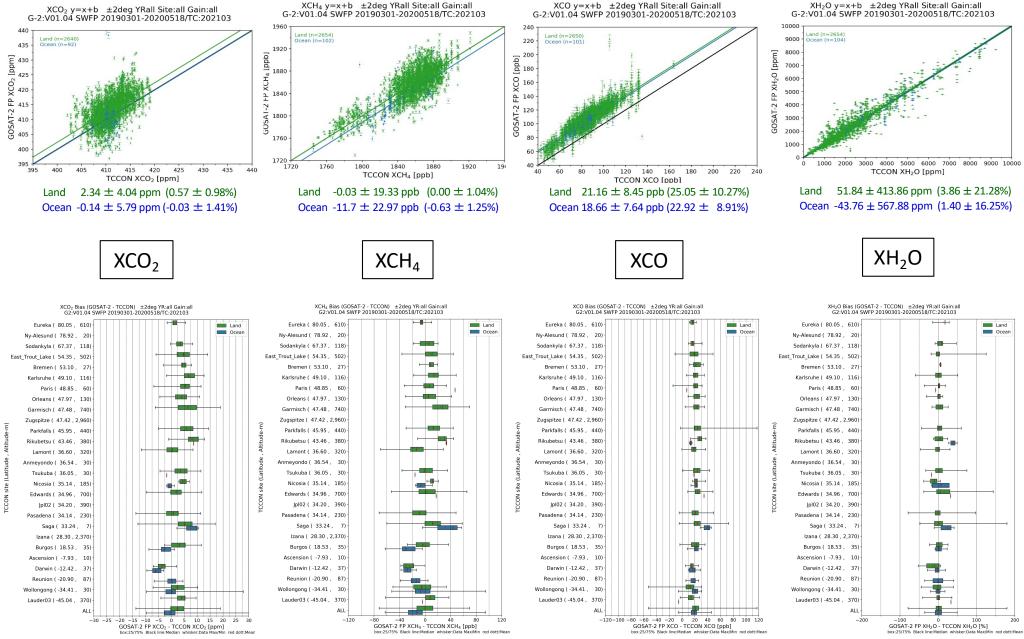


The aerosol observations using sky radiometers and Lidar have been conducted at Lauder, New Zealand. Relatively large AOT (0.15) and very negative ΔXCO_2 (-5.97 ppm) were observed at Lauder on October 7, 2015. This very negative ΔXCO_2 is lower than the value expected from the regression line (dotted line in the figure) in the scatter plot of AOT and ΔXCO_2 at Lauder (the green arrow in the figure).

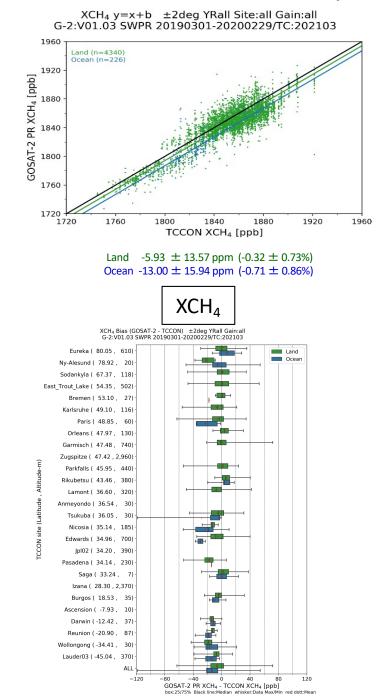
The stratospheric aerosols, probably originated from Calbuco volcano eruption, were detected by the Lidar measurement on the day in the vertical profile of aerosols. The very negative ΔXCO_2 on the day is supposed to be caused by the stratospheric aerosols. The very negative ΔXCO_2 in the scatter plot of SAOD and ΔXCO_2 at Lauder (the arrow in the right figure) supports this. Here, SAOD is derived by *Sakai et al.* (2016). Analyzed by Dr. Thi Ngoc Trieu Tran

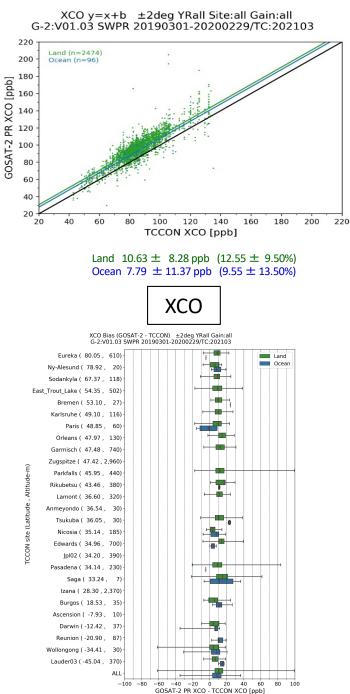
Ref. Sakai et al. (2016). J. Geophys. Res. Atmos., doi.org/10.1002/2016JD025132.

Scatter diagrams of GOSAT-2 FTS SWIR L2 full physics (V01.04) and TCCON at all TCCON sites and differences between them with 1 standard deviation (± 2 degree)



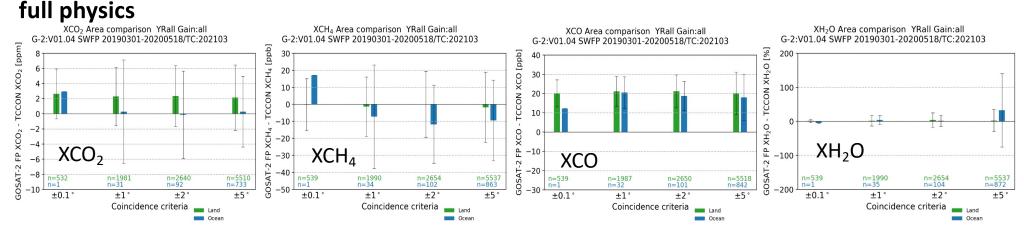
Scatter diagrams of GOSAT-2 FTS SWIR L2 proxy (V01.03) and TCCON at all TCCON sites and differences between them with 1 standard deviation (\pm 2 degree)





5

Biases by coincidence criteria for GOSAT-2 FTS SWIR L2



The biases of $\pm 0.1^{\circ}$ coincidence criteria for Ocean have only one case for XCO₂ and XCH₄, XCO, and XH₂O. So, they are excluded from the analysis.

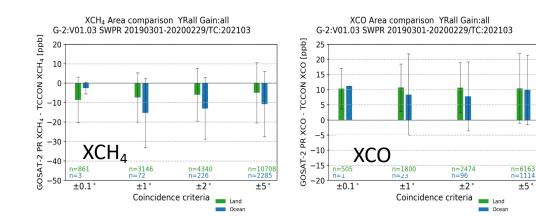
For XCO₂, the biases for Land are all positive and almost constant (~2 ppm) for all coincidence criteria. The biases for Ocean are very small, although the standard deviations are large.

For XCH₄, all of the biases are zero or negative. The absolute biases for Ocean are much larger than those for Land.

For XH₂O, the biases are small except $\pm 5^{\circ}$ coincidence criteria for Ocean.

PROXY

For XCO, the biases of all coincidence criteria are almost constant (~20 ppb), but those for Land are larger than those for Ocean.



The numbers of coincidence criteria of ± 0.1 for Ocean are very few for both XCH₄ and XCO, so they are excluded in the analysis. For XCH₄, the biases (GOSAT-TCCON) for Land and Ocean are all negative and the absolute biases are decreasing with broadening of coincidence criteria.

For XCO, the biases of every coincidence criteria are almost constant (~10 ppb), but those for Ocean are smaller than those for Land.